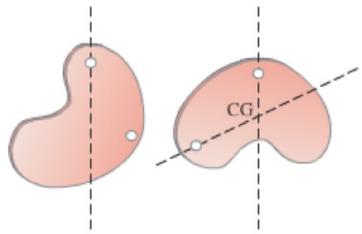


FIGURE 7–26 Finding the CG.

of the two lines, as in Fig. 7–26. If the object doesn't have a plane of symmetry, the CG with respect to the third dimension is found by suspending the object from at least three points whose plumb lines do not lie in the same plane. For symmetrically shaped objects such as uniform cylinders (wheels), spheres, and rectangular solids, the CM is located at the geometric center of the object.

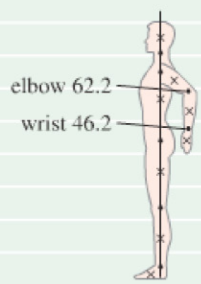
For some objects, the CM may actually lie outside the object. The CM of a donut, for example, lies at the center of the hole.

* 7–9 CM for the Human Body

If we have a group of extended objects, each of whose CM is known, we can find the CM of the group using Eqs. 7–9a and b. As an example, we consider the human body. Table 7–1 indicates the CM and hinge points (joints) for the different components of a "representative" person. Of course, there are wide variations among people, so these data represent only a very rough average. The numbers represent a percentage of the total height, which is regarded as 100 units; similarly, the total mass is 100 units. For example, if a person is 1.70 m tall, his or her shoulder joint would be $(1.70\,\text{m})(81.2/100) = 1.38\,\text{m}$ above the floor.

TABLE 7–1 Center of Mass of Parts of Typical Human Body
(full height and mass = 100 units)

Distance Above Floor of Hinge Points (%)	Hinge Points (•) (Joints)	Center of Mass (×) (% Height Above Floor)		Percent Mass
91.2	Base of skull	Head	93.5	6.9
81.2	Shoulder joint	Trunk and neck	71.1	46.1
		Upper arms	71.7	6.6
		Lower arms	55.3	4.2
52.1	Hip joint	Hands	43.1	1.7
		Upper legs (thighs)	42.5	21.5
28.5	Knee joint			
		Lower legs	18.2	9.6
4.0	Ankle joint	Feet	1.8	3.4
		Body CM =	58.0	100.0



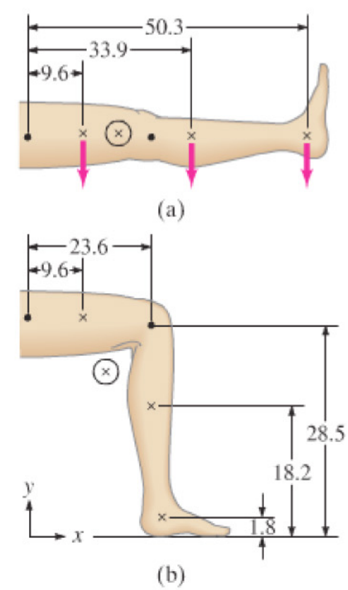


FIGURE 7–27 Example 7–13: finding the CM of a leg in two different positions using percentages from Table 7–1. (⊗ represents the calculated CM).

EXAMPLE 7–13 **A leg's CM.** Determine the position of the CM of a whole leg (*a*) when stretched out, and (*b*) when bent at 90°. See Fig. 7–27. Assume the person is 1.70 m tall.

APPROACH Our system consists of three objects: upper leg, lower leg, and foot. The location of the CM of each object, as well as the mass of each, is given in Table 7–1, where they are expressed in percentage units. To express the results in meters, these percentage values need to be multiplied by $(1.70\,\text{m}/100)$. When the leg is stretched out, the problem is one dimensional and we can solve for the x coordinate of the CM. When the leg is bent, the problem is two dimensional and we need to find both the x and y coordinates.

SOLUTION (*a*) We determine the distances from the hip joint using Table 7–1 and obtain the numbers (%) shown in Fig. 7–27a. Using Eq. 7–9a, we obtain

$$x_{\text{CM}} = \frac{(21.5)(9.6) + (9.6)(33.9) + (3.4)(50.3)}{21.5 + 9.6 + 3.4} = 20.4 \text{ units.}$$

Thus, the center of mass of the leg and foot is 20.4 units from the hip joint, or $52.1 - 20.4 = 31.7$ units from the base of the foot. Since the person is 1.70 m tall, this is $(1.70\,\text{m})(31.7/100) = 0.54\,\text{m}$ above the bottom of the foot.

(*b*) We use an xy coordinate system, as shown in Fig. 7–27b. First, we calculate how far to the right of the hip joint the CM lies, accounting for all three parts:

$$x_{\text{CM}} = \frac{(21.5)(9.6) + (9.6)(23.6) + (3.4)(23.6)}{21.5 + 9.6 + 3.4} = 14.9 \text{ units.}$$